Space Weather Technical Forecast

Issued on Saturday, 23 September 2023 at 13:26 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Isolated R1-R2 Minor/Moderate Radio Blackouts likely throughout. Risk of G1-G2 minor/moderate geomagnetic storms through the next four days, most likely 24 Sep (day 2).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate with four M-flares observed, the largest an M1.9 from AR3435 in the centre disc peaking 22/2300 UTC. This is the largest of the twelve sunspot regions on the disc, dominated by a main positive spot with smaller negative spots to its northeast and southwest. This has been the source of at least two CMEs, one to the northeast, originating from a long period Moderate flare which peaked 03/0336 UTC, and another to the south, the latter of which was from the M2.4 flare at 22/2258 UTC. AR3443 in the northwest disc complexified with notable flux emergence and a delta region developing through the last 24 hours, and produced a double peaked M1.5/M1.4 flare, with peak 22/1715 UTC. Analysis of the associated CME has this passing to the north and ahead of Earth. The other regions have remained less active.

Alongside the CMEs mentioned above, further faint CMEs were observed to the southwest and the northwest, due to coronal dimming events after the LP M1.2-flare. A number of other CMEs were also observed and assessed as likely off the Earth-Sun line, including a prominence eruption to the southeast and a slow CME off the northwest.

Solar Wind / Geomagnetic Activity: Solar winds, as measured at L1, fell from around 400 to 350 km/s with density around average or a little below. The Interplanetary magnetic field strength (IMF), Bt, was weak below 7nT, with the north-south component (Bz) also weak but predominately negative, ranging -6nT to +3nT. Phi angle was variable. Resultant Geomagnetic activity was Quiet to Unsettled (Kp1-3).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was at background. GOES16 high energy (greater than 2MeV) electron flux was initially moderate, but rose to high between 22/1210-2100 UTC, then again between 23/0225-0320 UTC, with a peak of 2550 pfu at 22/1555 UTC. Associated 24-hour fluence was below the Active (1e8 integrated pfu) threshold, but with an increasing trend to finish at 9.24e7 at 23/1200 UTC. The integrated pfu at 23/0000UTC was 8.02e7.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is forecast to be at mainly Low to Moderate levels. The main risk of M-class flares is from AR3435/38 in the centre disc and from developing region AR3443 in the northwest.

Solar Wind / Geomagnetic Activity: CME arrivals are possible through much of the period, with the most significant from the LP M1.2 flare on 22 Sep, likely arriving early on day 2 (24 Sep). Confidence is Low however, with further assessment ongoing of both this CME, other possible glancing impacts (including the M8.7 and M8.2 associated flares from previous days), and further CMEs that occurred on the 22 Sep. Otherwise, Earth is expected to move into the fast wind of coronal hole 51 day 1 (23 Sep), with enhanced winds potentially persisting due to CH52. Mainly Quiet geomagnetic activity at first, but with a risk of Unsettled to Active through

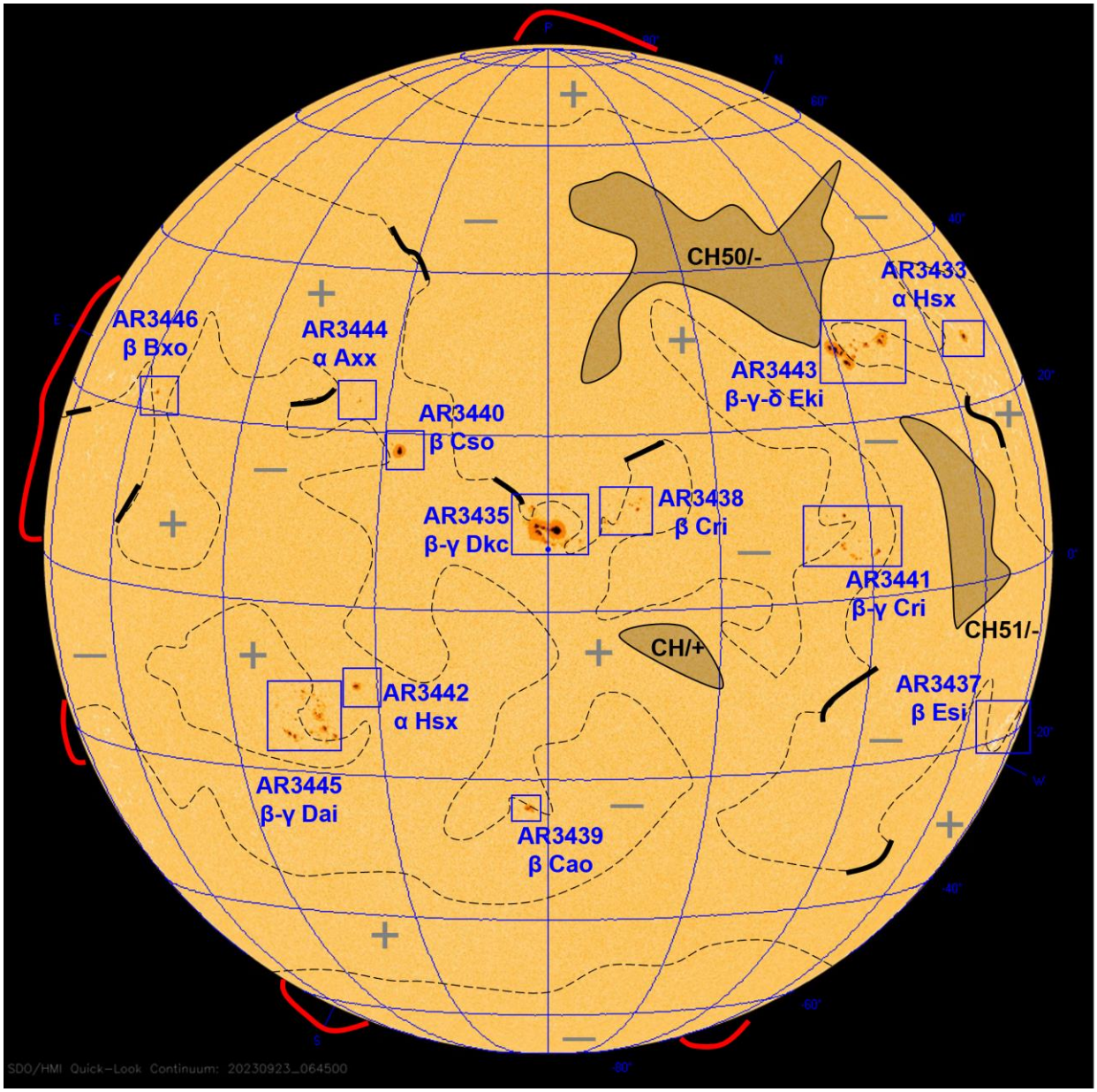
Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

much of the period and a risk of G1-G2 Minor to Moderate storms, most likely on day 2 (24 Sep).

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is expected to remain at Background levels, with a daily slight chance of an enhancement should any larger flares occur. High energy (greater than 2 MeV) electron flux is likely to remain at Moderate to High levels, giving a chance of Active fluence on day 1 (23 Sep), before likely dropping out with any high speed stream or CME arrival. Confidence in the electron forecast is then low as this will depend on the extent of any CME enhancement that occurs.

Figure 1. Solar Analysis Valid 23/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Geomagnetic Storms:

The geomagnetic forecast is currently low confidence due to the number of CME's that have recently left the Sun. The most significant CME is associated with the LP M1.2 flare, which peaked 22/0336 UTC. This was a fast and broad flare, and is expected to arrive on 24 Sep (day 2), with a chance of arriving late 23 Sep (day 1), albeit with much of the material likely passing behind (west) and north of Earth.

This may also be preceded by up to two glancing CMEs. The first was from the M4.0 flare and left the Sun on 19 Sep, most likely arriving earlier day 1. This may be followed by a CME from the M8.1 flare from AR3435 on 20 Sep, which has also be analysed as likely glancing Earth on 23 or 24 Sep, but with low confidence in timing. A further CME followed the M8.7 flare on 21 Sep and was analysed as likely arriving at Earth late on 24 or during 25 Sep (days 2-3). This is likely to be swept up into any arrival from the main CME mentioned above, but allows for an enhancement to occur should this CME miss. These CMEs all have very low confidence for their analysis.

There are also two further CMEs due to the coronal dimming events both early on 22 Sep. The first south of the AR3435/38 complex spot and a further one to the north of this region. These are both weak eruptions but give a slight chance of further enhancements on day 3 (25 Sep), and require further analysis. Other CMEs which feature in the forecast are from the double peak M1.5/1.4 flare at 23/1621 and 23/1714 UTC of AR3443 in the northwest and from the M2.4 flare at 22/2258 UTC from AR3435/38. These CMEs are currently expected to be missing Earth but may give slight glancing impacts, potentially combined within the material in the aforementioned CMEs.

Overall this gives a very low confidence geomagnetic forecast, with potential for it to range from successive CMEs arrivals, giving Minor to Moderate geomagnetic storming (most likely day 2, 24 Sep) to more Quiet conditions with solar winds dominated by the fast wind of CH51/50. These are expected to give minimal geomagnetic enhancement given their unfavoured polarity for the September Equinox, but are expected to increase solar winds to around 500 km/s day 1 (23 Sep) before easing later in the period. The greatest risk of Minor to Moderate storming is day 2 (24 Sep).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	30	40	30	20
Strong	G3	No	5	10	5	1
Severe	G4	No	1	2	1	1
Extreme	G5	No	1	1	1	1

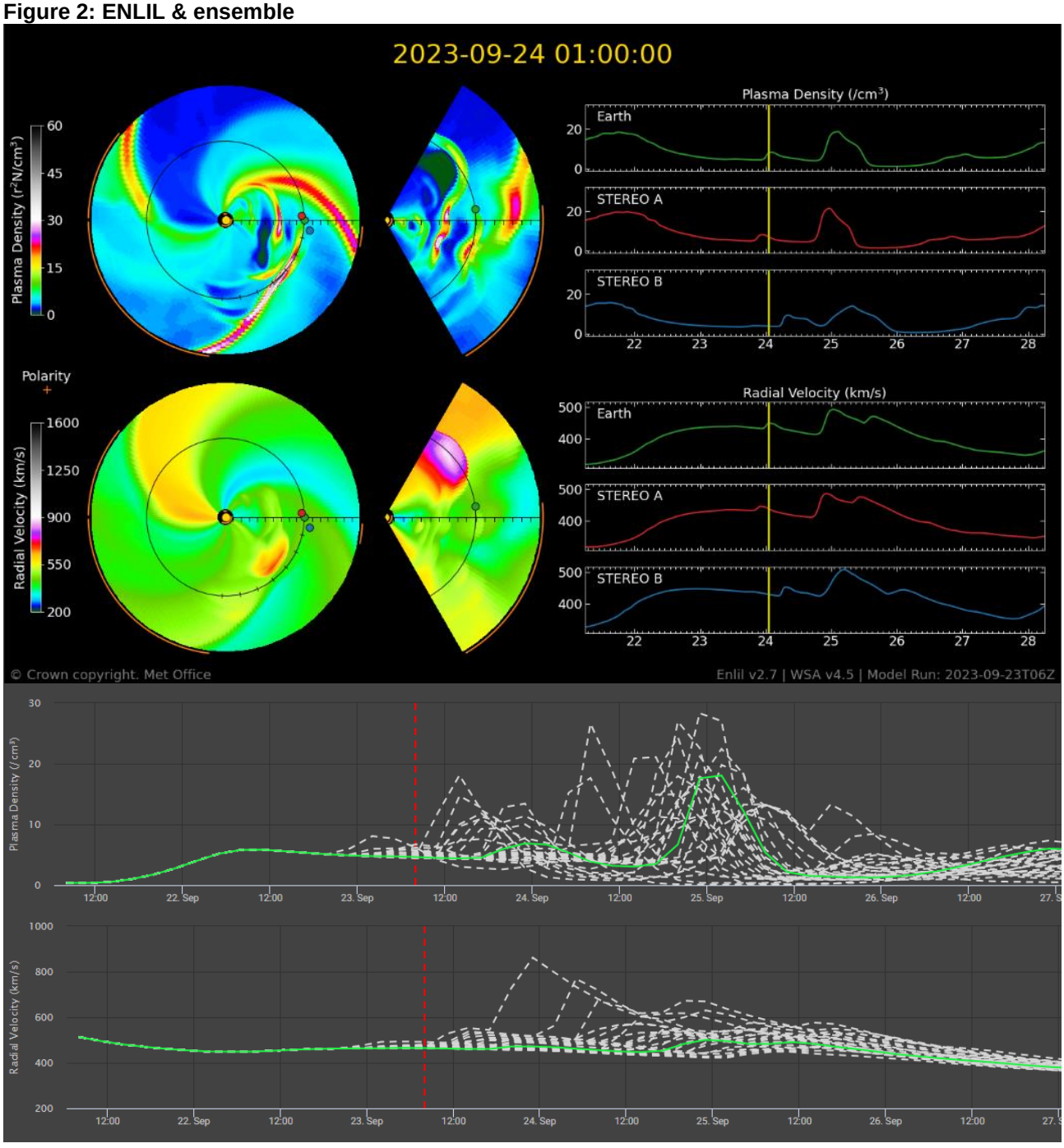
Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
20/2030	Partial	M8.1 AR3435	SE	550	23rd Sept	Glance, low confidence
21/2000	Partial	M8.7 AR3435	S	480	Late 23rd Sept/24th Sept	Glance, Low confidence
22/0534	Partial	M1.2 AR3435	NE	1200	Early 24th Sept	Low confidence

Figure 2: ENLIL & ensemble



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

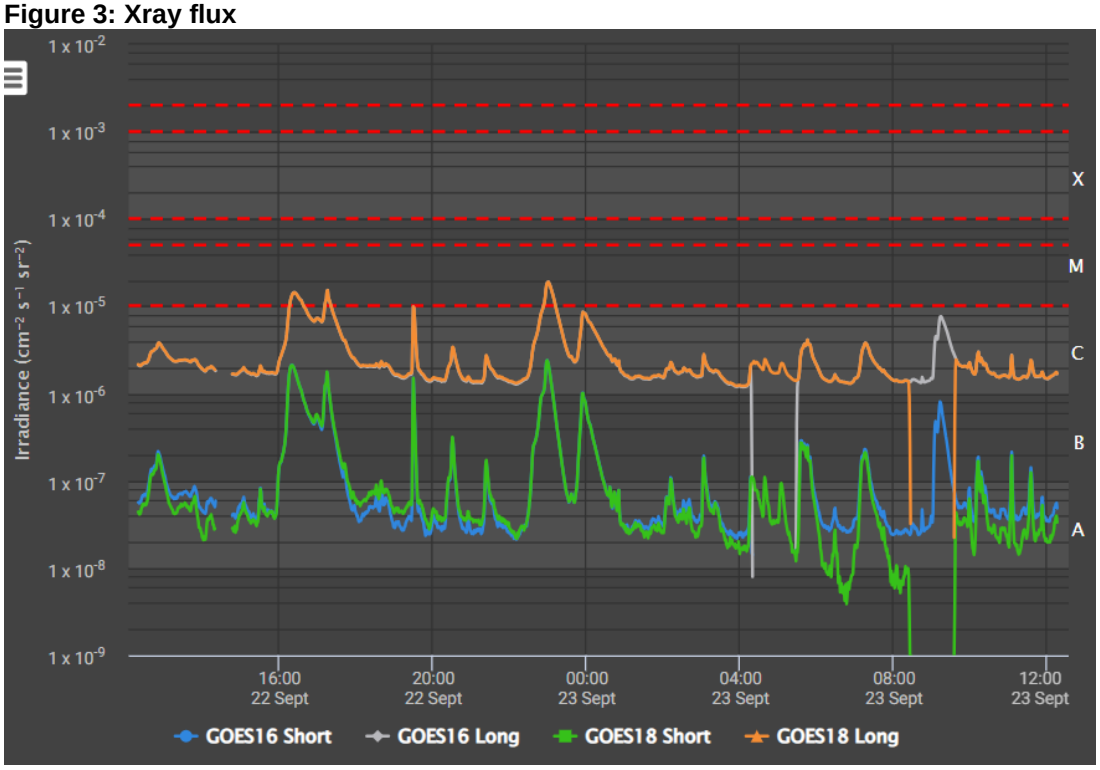
Radio Blackouts - X-Ray Flares:

Moderate activity is expected with an ongoing likelihood of further M-flares through the period.

Of the twelve active regions currently on the disc, two of which have a beta-gamma structure, and another with a beta-gamma-delta, these are the most likely source of any significant flaring. The beta-gamma-delta spot, AR3443 in the northwest, has been the most active recently. This remains magnetically complex with some small reverse polarity spots evident, although its composite small spots are showing some signs of consolidating into a simpler leader-trailer bipolar setup. Central disc AR3435 has shown little recent development, however persists as a complex region, dominated by a large positive main spot, with small negative trailers both to the northeast and northwest. This is also connected to the weaker spot AR3438, bringing some additional complexity, with significant looping evident between the two spots in SDO imagery. AR3445 in the southeast is the final region of note, as whilst it is composed of a number of smaller spots, there is some limited mixing of polarities, along with the ongoing proliferation of small spots as slight flux emergence continues.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	75	70	70	60
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: Xray flux



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

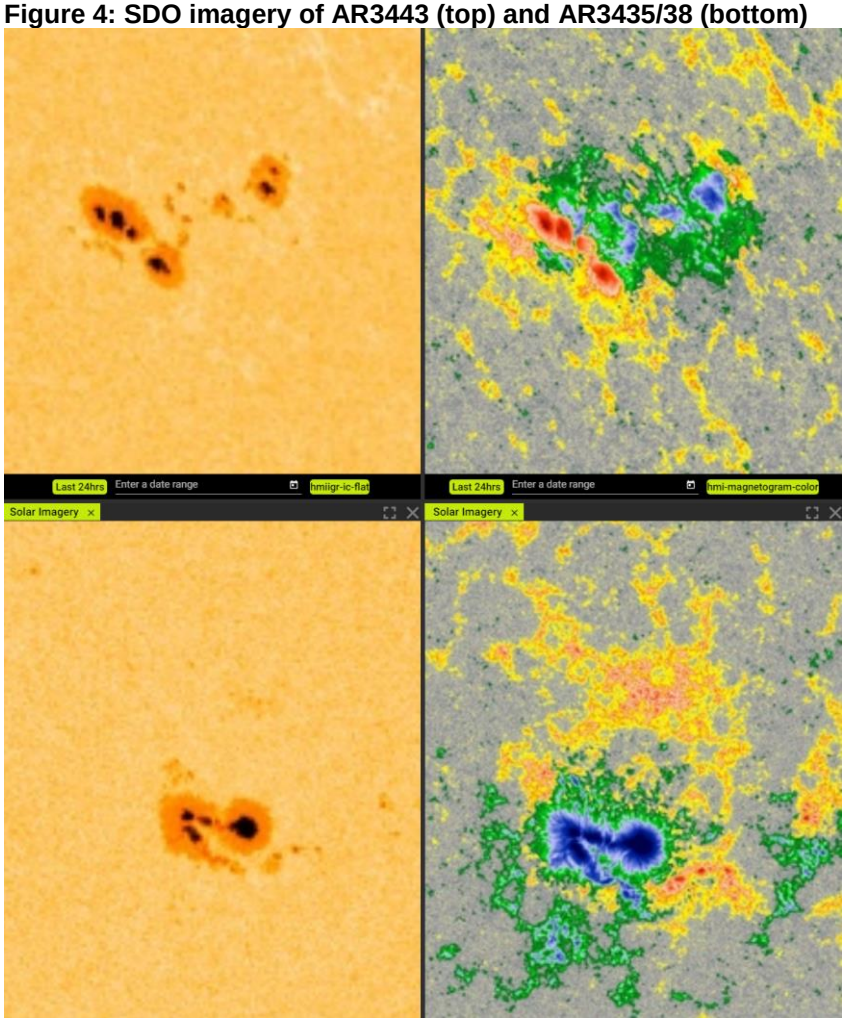
© Crown Copyright 2023. All Rights Reserved.

Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is likely to persist at background levels, however there are regions either on, or moving onto the western disc which bring an increase chance of flux levels rising above background given the occurrence of any significant flares. The most notable of these are AR3443 currently in the northwest and AR3435/38 in the centre disc. This brings a slight chance of exceeding the S1 Minor Radiation Storm level.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	15	15
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: SDO imagery of AR3443 (top) and AR3435/38 (bottom)



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

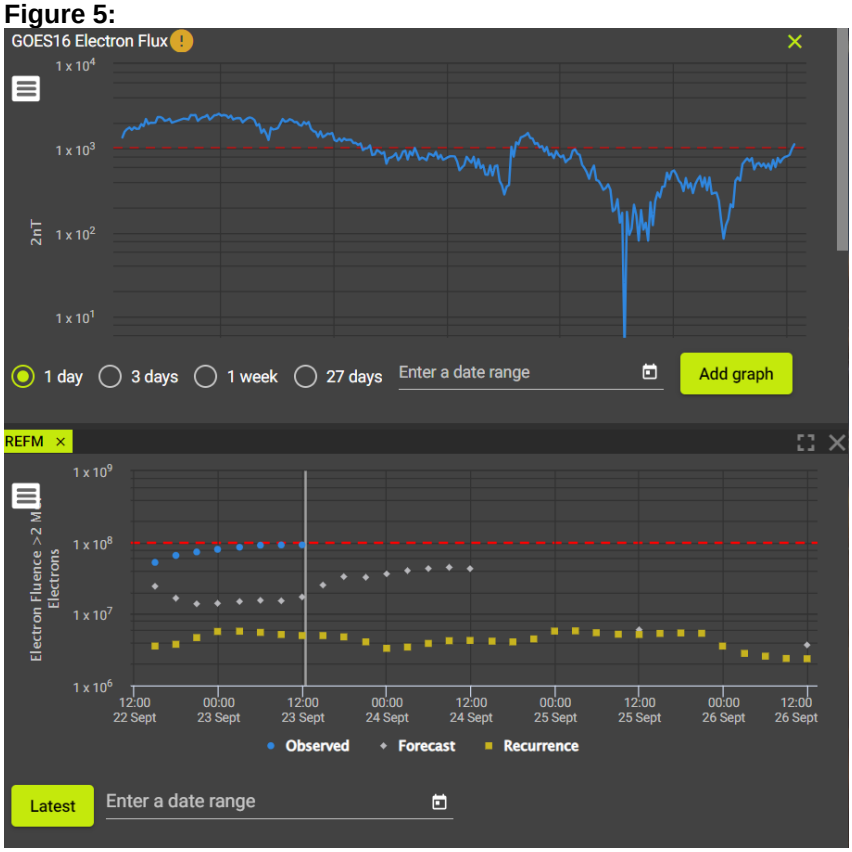
High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed by GOES16 has been moderate to high, as enhanced electron levels at lower orbits expand outward to GEO. This is expected to continue day 1 (23 Sep). Any solar wind enhancement, either from the onset of fast winds from CH50/51 or the arrival of the first of any of the CMEs that are expected, will likely drop values out to background. This most likely if the fast CME expected early day 2 (24 Sep) arrives as anticipated. As any enhancement eases this will allow the observed flux to recover to Moderate to High levels later in the period, however this is low confidence due to the potential for further CME arrivals.

The associated Electron fluence is expected to continue seeing a steady or rising trend day 1, with a chance of reaching Active briefly, before falling again in response to any drop out in observed flux caused by the potential CME arrival(s). This is currently above the REFM forecast, which doesn't take account of the recent increased electron populations at lower orbits. REFM will also be poor when any further CME arrivals occur.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	60	20	10	30
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5:



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.